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NIF Small Mirror Mounts

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Introduction

The most prominent physical characteristics of the 192-beam NIF laser are the 123 m length of the main laser and 400 mm aperture of each beam line. The main laser is illustrated in Figure 1, which shows half the total beam lines. Less visible are the many small optics (< 100-mm diameter) used to align and diagnose each beam line. Commercial mounts can be used for most of the small aperture turning mirrors. This paper reviews the NIF projects effort to identify suitable commercial mirror mounts.

The small mirror mounts have stability, wave front, space, and cleanliness requirements similar to the large aperture optics. While cost favors use of commercial mounts, there is little other than user experience to guide the mount qualification process. At present, there is no recognizable qualification standard with which to compare various products. In a large project like NIF, different user experience leads to different product selection. In some cases the differences are justified by application needs, but more often the selection process is somewhat random due to a lack of design standards. The result is redundant design and testing by project staff and suppliers. Identification of suitable mirror mounts for large projects like NIF would be streamlined if standards for physical and performance criteria were available, reducing cost for both the project and suppliers. Such standards could distinguish mounts for performance critical applications like NIF from laboratory applications, where ease of use and flexibility is important.

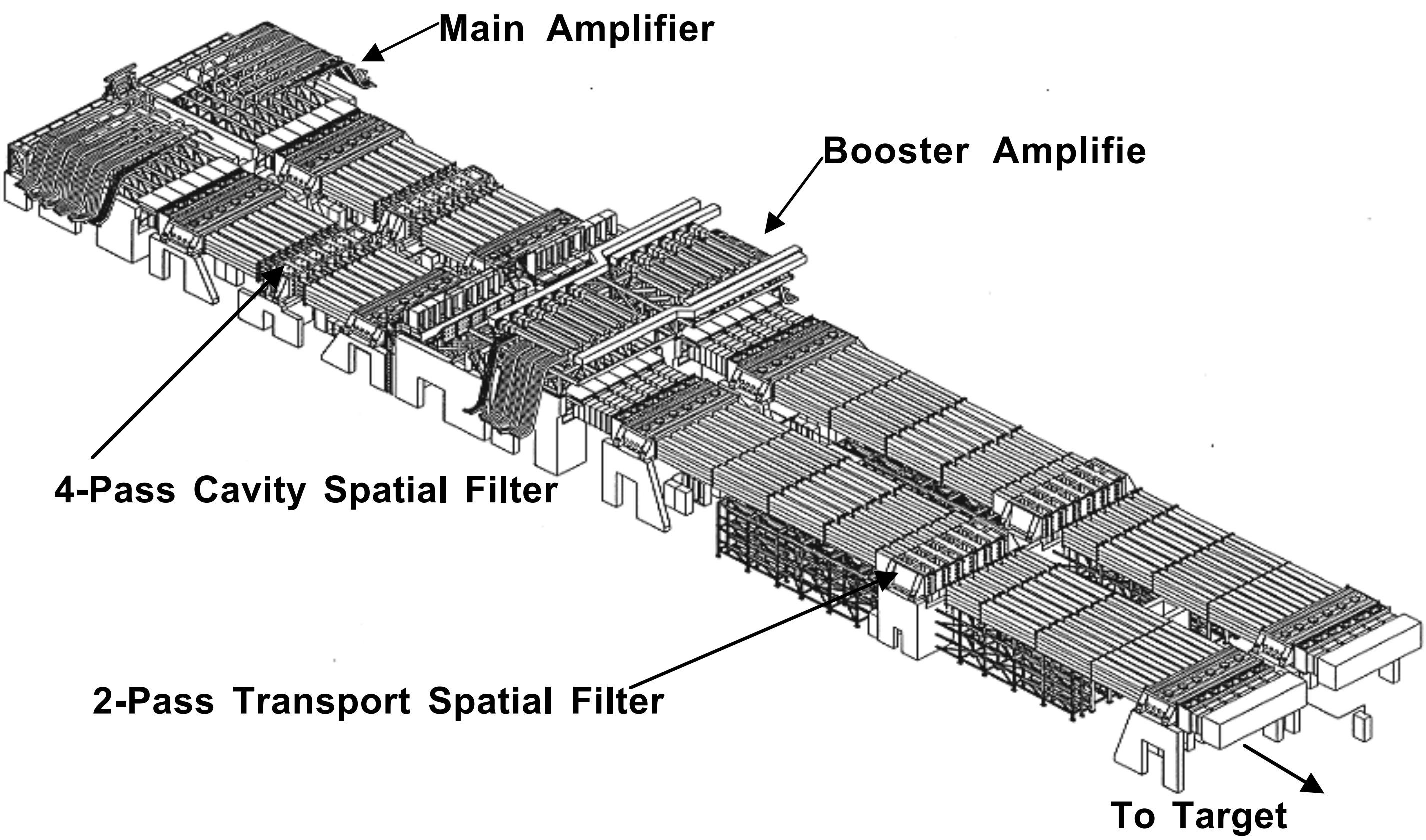

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Figure 1. Overall view of the NIF main laser. The location of the Transport Spatial Filter, where many small optics reside, is noted. This layout shows half of the 192 beam lines, or two of the four beam clusters.

NIF Alignment and Diagnostic Beam Lines

In the NIF architecture the alignment, injection, and diagnostic beams enter and exit the main laser in close proximity to each other through the bottom of the Transport Spatial Filter (TSF) vacuum vessels. The physical layout for this area, where many of NIF's small aperture optics reside, is shown in Figure 2. The injected beam enters through a vacuum window and is directed to the left of the figure, where multi-pass amplification and wave front correction occur. After amplification the beam is directed back through a pinhole spatial filter on the alignment tower before continuing on to the target chamber. Vacuum is required at the spatial filter pinhole to avoid ionizing background gas, but most of the main laser outside the spatial filter area is at atmospheric pressure.

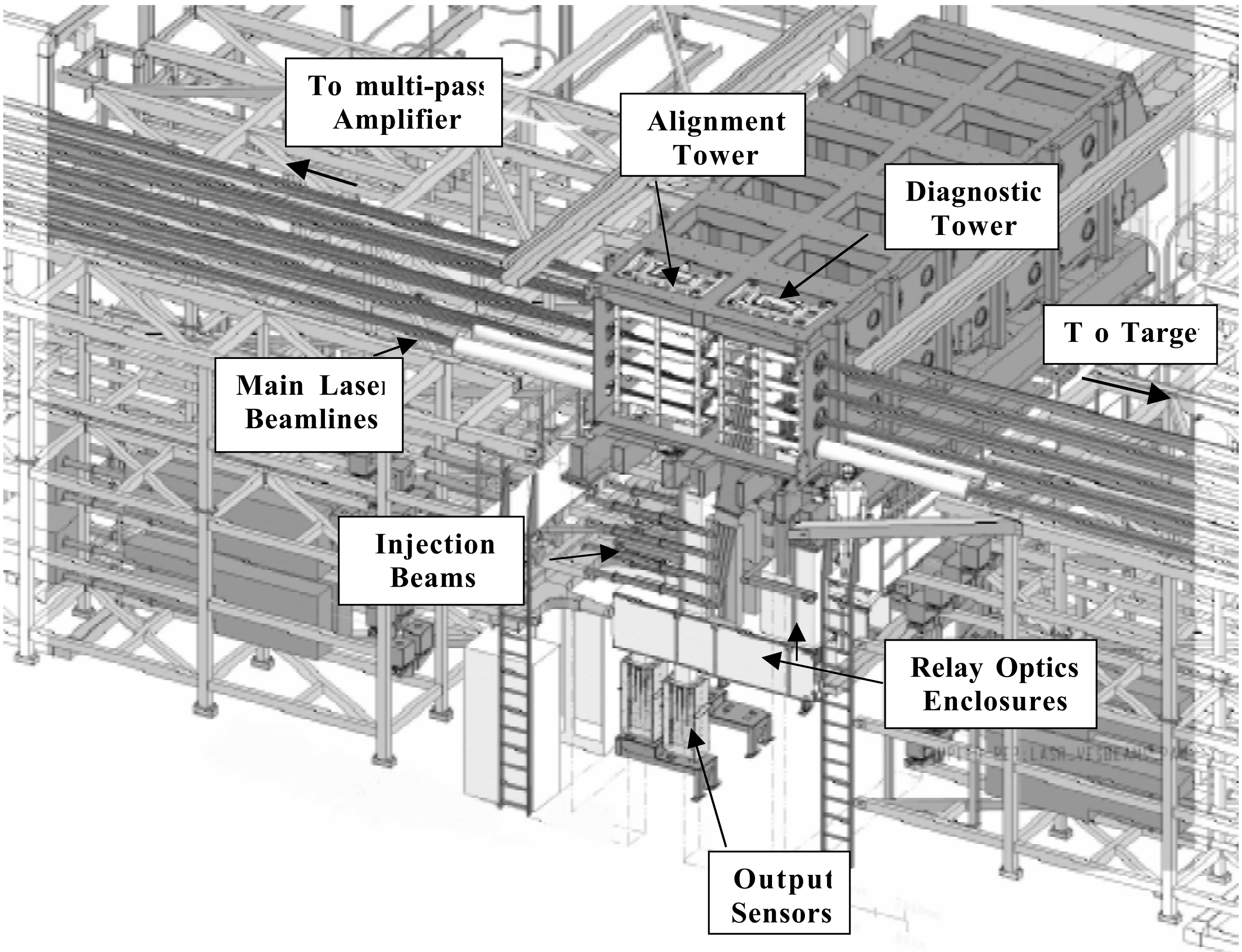

Figure 2. A cut away view of the NIF spatial filter transport region, showing injection, alignment, and diagnostic beams. (The concrete walls that support the vessel are shown as dotted lines to facilitate the view).

The alignment and diagnostic towers shown in Figure 2 inside the TSF vacuum vessel are line replaceable units that support lenses and mirrors used to transport alignment and diagnostic beams through vacuum windows to relay optics below. Each tower pair supports eight high power beam lines; a beam "bundle". Each tower has four platforms stacked one above the other, as shown in Figure 3 for the diagnostic tower. The alignment tower is similar, but has different platform components.

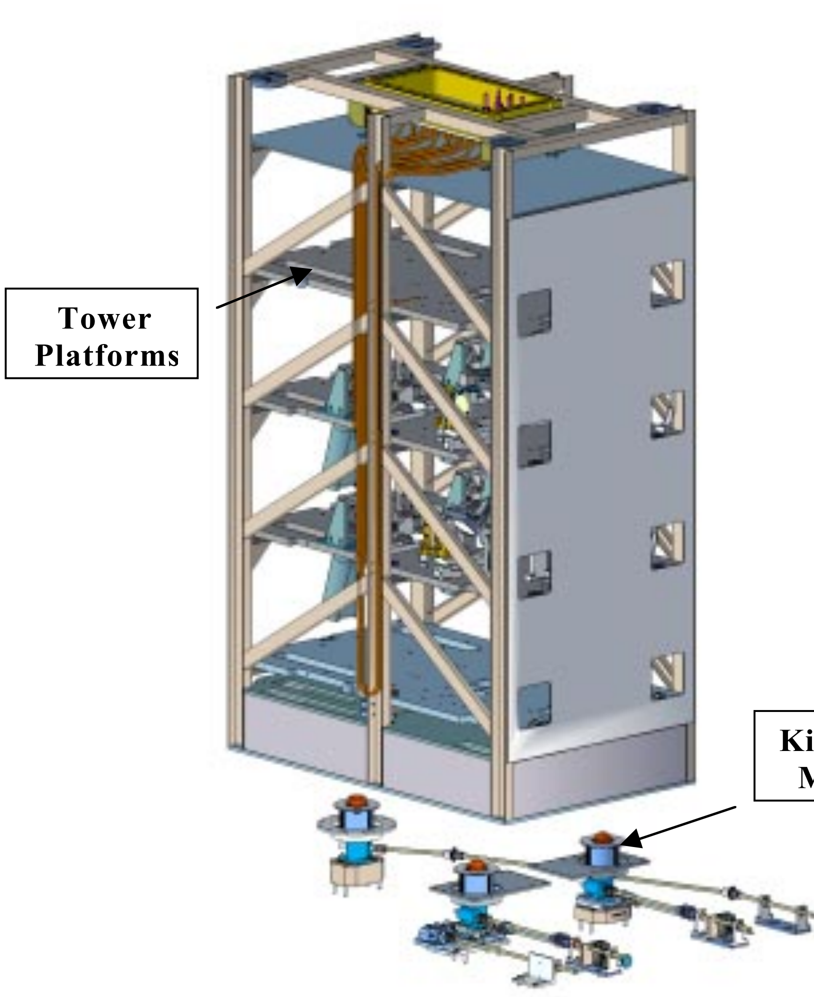

Figure 3. Each tower structure supports four platforms, with two beam lines per platform. The structure rests on kinematic mounts to ensure position repeatability upon replacement.

Components on the alignment and diagnostic tower platforms are shown in Figure 4. The alignment platform supports the pinhole spatial filter as well as optics and electro-mechanical devices used in laser alignment. The diagnostic platform supports the laser injection telescope & turning mirror, as well as optics & electro-mechanical devices used in diagnosing 1 micron wavelength and frequency tripled beams returning from large aperture sampling surfaces.

The physical interface between beams entering the towers and the fixed optics below is critical. The alignment and diagnostic relays below the towers lead to an output sensor used for alignment, wave front, temporal, and spatial power measurement. To satisfy the optical interface between the tower and relays, tower mirror mounts must be stable, minimize distortion, be compatible with highly reflective and transmissive optics in vacuum, and accommodate tight space constraints. These requirements are described further in the following sections.

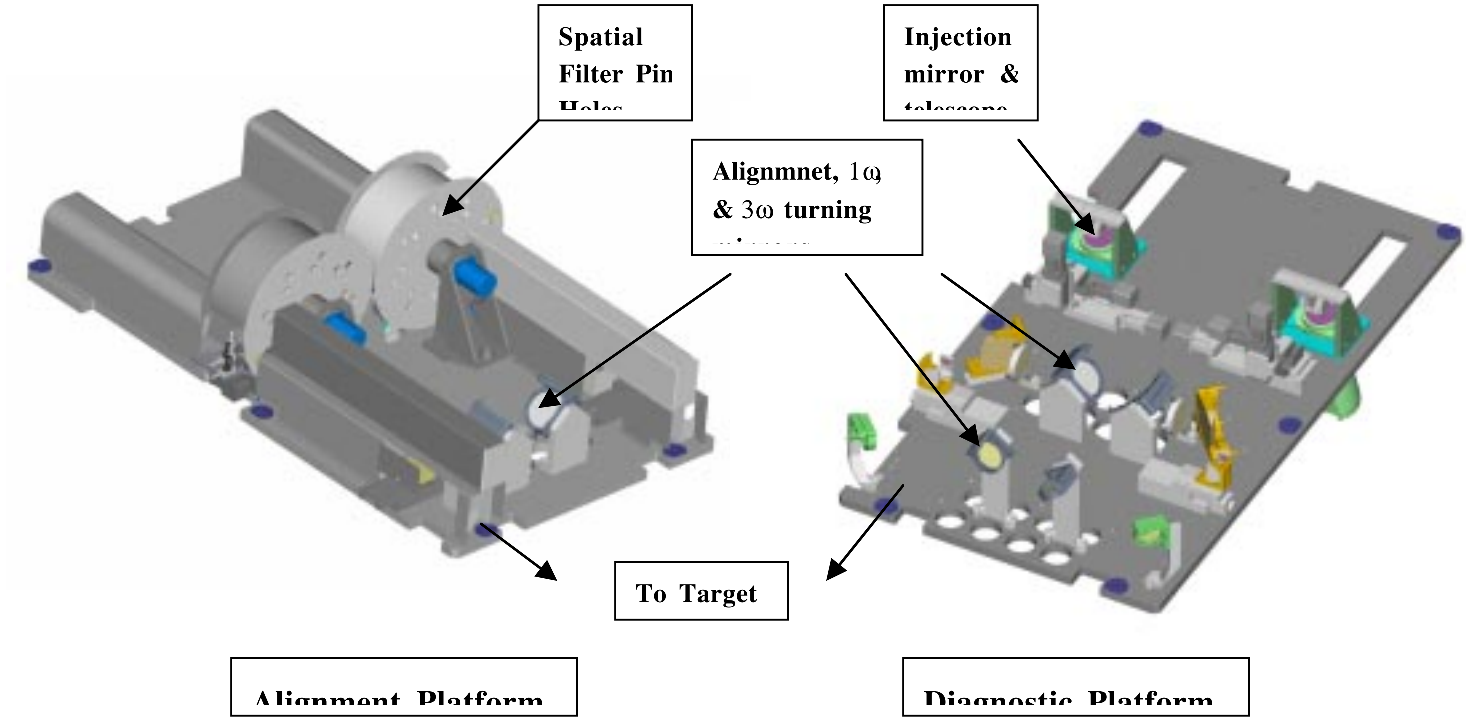

Figure 4. Component layout on the TSF alignment and diagnostic tower platforms.

1.Mirror Mount Stability

For each main laser beam line there is one alignment beam and two diagnostic beams (1ω and 3ω) directed toward the output sensor. Summed over the eight beams in a bundle, a total of 48 tower mirror mounts must be aligned to the relays below. When a new tower is installed, the mirror mounts must deliver the alignment and diagnostic beams within a tolerance of 150 microns and 100 micro-radians relative the relay optic paths. If this requirement is not met, then turning mirrors in the relay optic path have to be adjusted, resulting in costly laser down time.

Adjusting tower mirror mounts when the towers are in the TSF vessel is not viable, as there is no room for personnel inside the vacuum vessels. Motorizing each mirror for active alignment after installation was ruled out as prohibitively expensive.

The selected approach is to replicate the main laser alignment and diagnostic beam paths on a tower assembly stand within an accuracy of 20-30 microradians, and pre-align tower turning mirrors using these surrogate beams. Pointing and centering is adjusted to meet the interface requirement to the relay optics by comparing the beam centroid at two points along the beam path to accurately located fiducials. The tower assembly stand used for this operation is shown in Figure 5.

Once tower mirrors are pre-aligned, the tower itself is precisely located inside the vacuum vessel relative to the relay optics interface using kinematic mounts. The tower position must be repeatable upon insertion into the vacuum vessel within 10 microradians.

Vibration stability of the mounts is critical during tower transport from the alignment stand to the main laser. Out of a 100 micro-radian interface budget with the relays, only 10 micro-radians can be spared for mount vibration stability during tower transport and insertion. Vibration stability tests conducted on candidate mounts quickly separated designs qualified for NIF application from those suited to less rigorous service. The design process would have been significantly expedited if candidate mounts had been pre-qualified to stability standard.

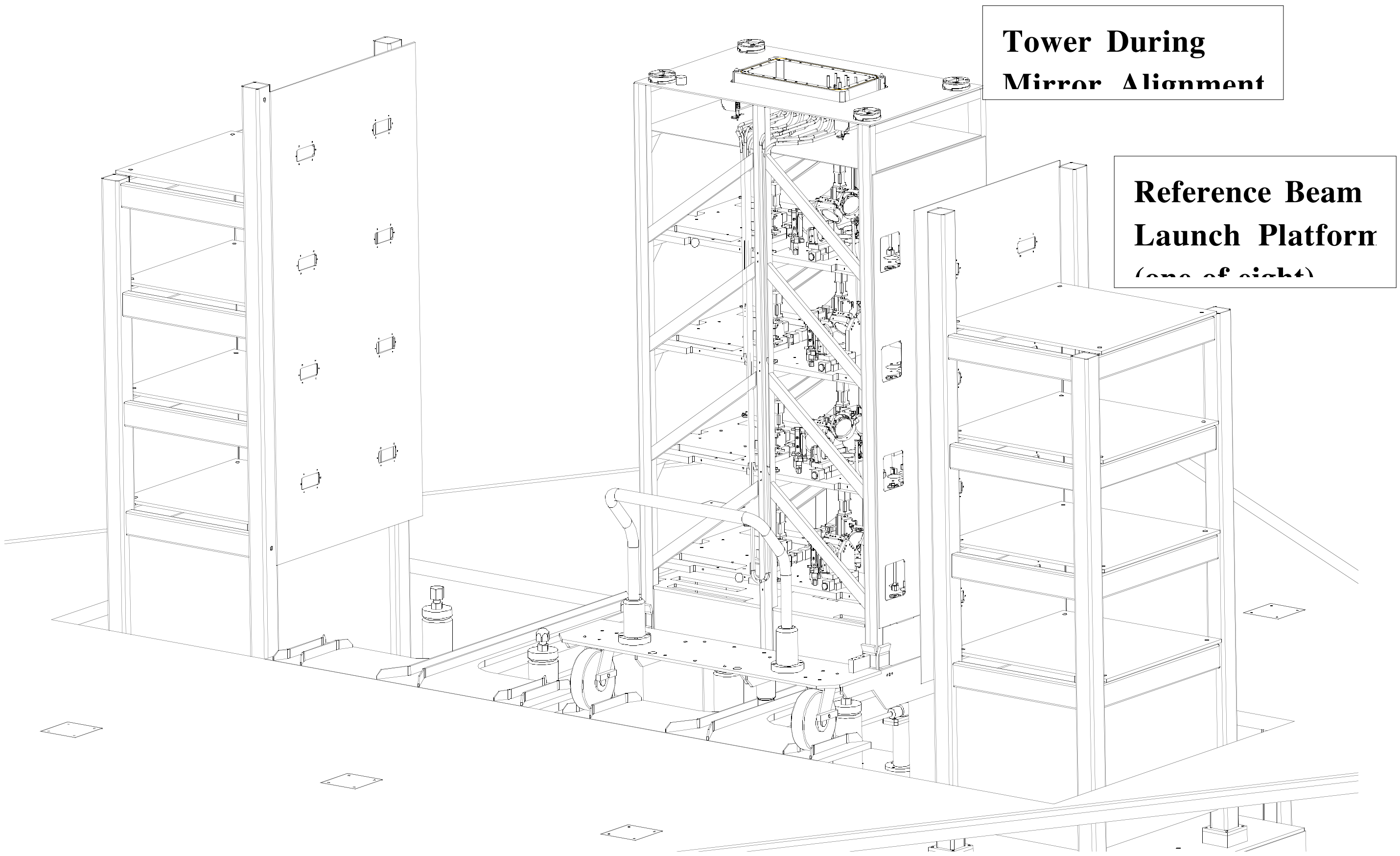

Figure 5. The tower assembly stand with diagnostic tower in place. The assembly stand accurately replicates the main laser injection, alignment, and diagnostic beams relative to the tower kinematic mounts. Calibrated detectors below the towers are used to point and center tower turning mirrors.

2. Physical Features

Tight space constraints on tower platforms required careful consideration of component layout during optical design. Physical features of the mirror mounts are an important facet of component layout. Standard parameters for key physical features were established to facilitate component layout and communicate physical interface requirements to mirror mount suppliers.

Important physical features include:

- The distance from mirror face to the bolt pattern at a mounting bracket.
- The distance from the mirror axis centerline to the surface interface at a mounting bracket.
- The size, spacing, and type of bolts to interface with a mount support bracket.
- The mirror diameter, thickness, and tolerances the mount must accommodate.
- The physical interface between the mount and mounting bracket that provides stable three-point contact.

With these parameters established early, and communicated to mirror mount suppliers, the mechanical designer can lay components out with confidence that multiple mount suppliers are available to meet the physical interface requirements. Optical designers can proceed in parallel with assurance that optic placement will not require adjustment later on due to unplanned physical interference.

3.Wave Front Considerations

Part of the overall wave front budget for the alignment and diagnostic beams is allocated to the mirror mounts. Mount features that influence performance include the mirror thickness to diameter ratio, and the manner of support. For mirrors less that 150-mm in diameter, a thickness to diameter ratio of 1 to 6 was chosen to make gravity distortion negligible.

The manner of supporting small mirrors is to use three contact points spaced 120º apart that contact opposite sides of each mirror face. This arrangement minimizes mount induced bending stress. The pressure on the contact points is just enough to prevent the mirror from vibrating in the mount during transport, but not enough to cause significant stress induced distortion away from the contact points. The requirement for mount induced wave front distortion must be less that 1/10 wave, peak to valley. Distortion is very sensitive to radial force, so no point contact radial constraints are applied. The mirror must fit snuggly into the mount to avoid shifting during transport.

The support concept above was communicated to potential suppliers, and the performance of candidate designs was measured. A number of satisfactory designs were identified. There are many “off the shelf” designs that do not have these design characteristics, and do not satisfy the wave front distortion requirement.

4.Cleanliness Standards

The TSF vacuum vessel and tower are both cleaned and maintained to level 100 particulate cleanliness levels as defined in MIL-STD-1246C. This requirement is driven by the need to control light loss from obscuration. Most mirror mount suppliers understand this standard and can comply using in house or a contracted cleaning service.

The organic cleanliness requirements for surfaces are specified as A/10 in (see MIL-STD-1245C), or 1 mg/m^2 of surface area. The need for this requirement has been demonstrated by exposing anti-reflection coated optics to organic contaminants. Organic contaminants in the molecular weight range of 50 – 100 AMU vaporize and transport quickly under vacuum, forming a thin film deposit on anti-reflection coatings that degrades lens transmission and mirror reflectivity. The partial pressure of these contaminants can be as low as 10^{-12} Torr, barely measurable by vacuum technology, and still effect the coatings over time.

Because organic contaminants are difficult to detect a priori, many mount suppliers may not know how to reach a given organic surface contamination requirement. Fortunately, organic contaminants are effectively removed by a number of simple cleaning processes. The simplest method of removing organic contaminants from components is to apply thermal energy and a surfactant. For example, the NIF vacuum vessels are cleaned by an elevated temperature spray wash and rinse followed by an air-dry cycle. Smaller components are immersed in elevated temperature baths, where ultrasonic cleaning can be simultaneously applied to remove particulates. Alternatively, the mount can simply be oven baked followed by hand wiping for particulate removal. All these approaches have been demonstrated for NIF components. The approach selected for mirror mounts depends on the type of cleaning equipment available to the supplier.

5.Summary

A number of small mirror mounts have been identified that meet the stringent stability, wave front, and cleanliness standards of the NIF. These requirements are similar to those required in other performance critical optical design applications. Future design teams would conserve time and effort if recognized standards were established for mirror mount design and performance characteristics. Standards for stability, physical features, wave front distortion, and cleanliness would simplify the qualification process considerably. At this point such standards are not difficult to define, as the technical support work has been performed repeatedly by mirror mount consumers and suppliers.